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RESTORATION OF DRINKING WATER PIPING WITH NONTOXIC EPOXY LININGS

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ABSTRACT

It is now possible to rehabilitate deteriorated drinking water systems by installing a non-toxic lining which prevents corrosion and leaching of lead and other heavy metals into drinking water. This method is (1) rapid (less than 48 hours), (2) suitable for use aboard ship, inside buildings and underground, (3) effective in bent pipes and pipes of different diameters, (4) economical compared with the cost of replacing pipe, (5) practical for pipe diameters between 1/8" and 24", (6) useful in pipe runs of 1000 feet, (7) suitable for drinking water, waste water, fuel, and other fluids, and (8) minimally disruptive of tenants and their activities. It is recommended for fast, economical, in-place rehabilitation of drinking water systems at Defense facilities around the world.

INTRODUCTION

Corrosion of water mains introduces impurities into drinking water. When these impurities are heavy metals such as lead, the quality of the water may fail to comply with the requirements of the Safe Drinking Water Act and other regulations. The usual remedies for this situation are to replace the piping or to bring in bottled drinking water; several Navy facilities have actually been taken out of service when their drinking water did not measure up to federal standards. This talk will describe another solution - lining the interior of the pipe with a nontoxic coating which keeps impurities out of drinking water.

A chemically-resistant nontoxic epoxy lining for water pipes has been developed at the Naval Research Laboratory. This lining is applied to the interior of pipes by compressed air. The operation causes minimum disruption to tenants or their activities and may be used on systems with multiple bends and varying diameters of pipe. Piping may be lined without removal or disassembly and returned to service within 24 hours. The Navy intends to use this technology for fast, economical rehabilitation of drinking water systems aboard ship and at shore facilities around the world.

BACKGROUND

This lining was originally developed to solve corrosion problems aboard aircraft carriers. These ships experience severe erosion and corrosion of piping in their waste collection systems, known as collection, holding and transfer (CHT) systems. The Naval Sea Systems Command Detachment responsible for planning and engineering for repairs and alternations of carriers (PERA-CV, Bremerton, Washington) proposed that these piping systems be lined with epoxy linings as part of their Carrier Life- Enhancing Repair Program. As a test, a 20-foot section of CHT pipe aboard the USS MIDWAY (CV 41) was lined in Japan in mid-1986.

Following this favorable test, PERA-CV tasked NRL to test commercial bisphenol epoxy coatings for properties which are significant for CHT piping system linings. The tests were selected jointly by PERA-CV and NRL. None of the commercial coatings was found to be suitable for aircraft carrier CHT systems.[1] Common problems were short pot life, air entrainment during application, and poor adhesion to the copper-nickel alloy pipe. All of the commercial coatings contained solvent; solvents never leave a paint film completely and are always a risk for contamination of water.

PERA-CV then tasked NRL to develop suitable Navy reference formulations for lining 90/10 and 70/30 copper--nickel pipes in both CHT and potable water systems. These coatings have several unique requirements. They must be at least as good as the 1987 standard, a commercially-available Devoe 143 coating (which hardened too fast for convenient use), and they must be formulated from materials approved for use with drinking water so that the same coating may be used in potable water and CHT pipes. They must also be suitable for application by commercial pipe lining methods which rely only on a pressurized gas to propel the paint through the pipe being coated.

We have developed a series of two-component epoxy linings, now known as the "NRL Series 4" linings. The formulations were deliberately kept as simple as possible. The first component contains a liquid epoxy resin, red iron oxide as a colorant, and hydrophobic fumed silica to give body and resistance to flow. The second component, a curing agent, varies in each of the "Series 4" linings.

The coatings were tested in the laboratory for resistance to a wide range of materials found in sewage systems before being approved for a shipboard trial. Initial lab tests sometimes produced films with air bubbles. These provide paths for oxygen, sulfides, and other reactive species to reach the copper-nickel pipe and corrode it, and could not be tolerated. Additives to eliminate entrapment of air were studied and three materials were identified which prevent the formation of bubbles. However, changes in the lining application process were implemented which successfully eliminated bubbles, making unnecessary any changes to the formulations of the linings.

The program was temporarily delayed when new federal legislation[2] governing the manufacture of the curing agent used in the NRL 4A coating caused the sole producer to stop selling this product. The regulations did not ban production of the material but required all who made or used it to maintain medical records for 30 years, a requirement deemed to be unreasonably costly. Thus it was necessary to reformulate and retest the lining for drinking water applications. Replacement curing agents were identified and tested, using procedures identical to those used in the development of the original lining. All chemical resistance properties and physical characteristics of the original coating were retained in the reformulated product. Linings found acceptable in the laboratory were tested in the field using the same equipment and procedures. A replacement lining, known as NRL 4B, was quickly developed and proven. We have applied for a patent on this coating, and inquiries regarding licensing have been received from commercial applicators.

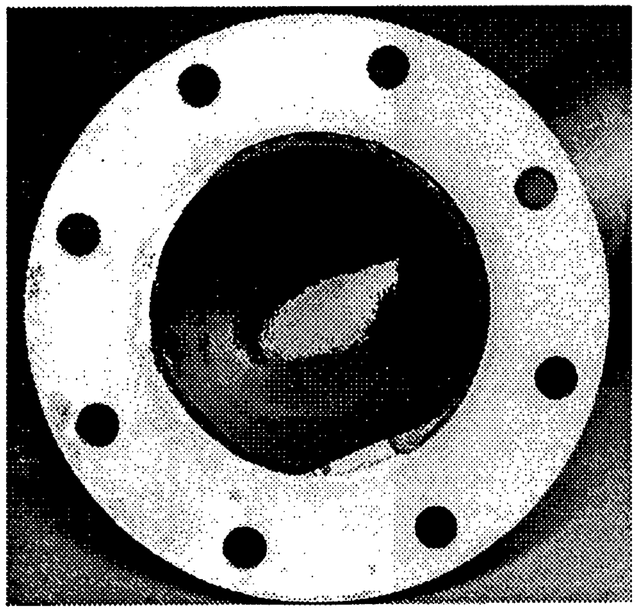

Figure 1. A pipe elbow from the USS AMERICA (CV 66) lined with the nontoxic epoxy lining. Note the increased thickness on the bottom.

The process used to line shipboard sanitary piping systems was worked out in detail by the American Pipelining Corporation (San Diego, CA),[3] PERA-CV, and NRL. In the past 8 years, sanitary piping systems aboard 12 carriers have been lined. Figure 1 shows an elbow of 6-inch diameter copper--nickel piping from the USS AMERICA (CV 66) which was lined in November 1988 and removed after two years of service. Note that the coating is thicker at the bottom than at other places in the pipe; this is not a disadvantage since almost all corrosion occurs there and the added protection of a thick lining is valuable.

This process is now used routinely on aircraft carriers. The lining has now been installed in all active (and many now decommissioned) carriers and is specified for installation in all new aircraft carriers during construction. In November 1995 the USS JOHN C STENNIS (CVN 74) was the first carrier delivered with the lining already installed. At present two private firms in the United States install this lining.[3]

LININGS FOR DRINKING WATER PIPES

The technology used aboard aircraft carriers is directly transferrable to piping systems at shore establishments. It comprises the same nontoxic lining and the same process to install it. The chemically-resistant nontoxic epoxy lining for water pipes is known as NRL 4C, and differs from 4A and 4B only in the curing agent used. The lining contains no solvents, dries in 20 minutes, and resists severe mechanical abuse. The lining releases no color, taste, odor or leachable material into the water.

Materials in contact with drinking water must be tested and approved by the National Sanitation Foundation (Ann Arbor, Michigan) for compliance to NSF Standard 61[4]. NSF, a not-for-profit organization, is the only firm authorized by the Environmental Protection Agency to test and approve materials for contact with drinking water. The testing is in three parts: A review of the properties and history of the ingredients of the lining; application of the lining to pipe, extended contact with water, and tests of the water to ensure nothing has been extracted into it; and examination and certification of manufacturing facilities to ensure that the lining is not contaminated with extraneous material. Because of the requirement that manufacturing facilities must be approved, only manufacturers can obtain NSF certification. To make certification more rapid and less expensive for manufacturers, NRL funded the first two phases of the certification procedure. American Pipelining Corporation has now obtained NSF certification for the NRL 4C lining for use in hot and cold drinking water systems.

The application procedure involves three steps: inspection and necessary repairs before lining; surface preparation by abrasive grit propelled by compressed air; and application of the lining. The technique does not completely eliminate the need to replace deteriorated piping. At the outset of a job pipe thickness is measured with ultrasonic techniques. Pipe with more than 50 percent of its original wall thickness can be lined, but pipe thinner than this must be replaced before lining begins. Pressure in the pipes can reach 60 psi and, although this is not usually considered high pressure, precautions must be taken against rupture of the pipe. Usually only a small amount of pipe is replaced. Lead-based fittings and old solder are removed to the extent possible. Mechanical (flange) joints are installed in the system where it may be necessary to open the system in the future; this is intended to eliminate any future need to cut the pipe and damage the coating.

This technology has been shown to be a proven inexpensive alternative to replacement of pipe, and the Navy now intends to extend this technology to fast, economical rehabilitation of drinking water systems aboard ships and at shore facilities around the world. Pipes are lined without removal or disassembly. Trailer-size air compressors are placed outside the building and air hoses lead inside where they are connected to the piping system. A hose on the other end of the pipe leads outside to a dust collector. Hot dry air is blown through the pipe, and grit is added to remove rust and other contaminants and give the inside of the pipe a rough surface. A 50-micrometers (2 mil, 0.002 inch) profile is required, and is monitored at the front and back of the pipe by making an impression of the profile with replica tape and measuring the profile on the tape with a micrometer. Immediately after cleaning freshly-mixed paint is blown through the pipe, where it hardens in about 20 minutes. Two to three coats are applied in opposite directions to ensure that pinholes and "shadow" areas where the pipe changes diameters are completely covered. The final paint thickness is 300 ± 75 micrometers (12 ± 3 mils). The stream of hot air is maintained for about 12 hours to dry the paint thoroughly. Pipes are reassembled, flushed with water to remove any contaminants, and pressure tested before the water system is placed back in service. The pipe can be returned to service within 48 hours.

The operation is fast and causes minimum disruption to buildings or their occupants. It is suitable for pipe inside ships and buildings or underground, and is economical compared with the cost of replacing pipe. It may be used on pipe runs as long as 1000 feet, even if they have numerous bends and varying diameters. Temporary water distribution networks are usually installed so that routine activities may continue without disruption.

This method has several disadvantages. No welding or other hot work can be performed on the lined pipe, but soldering is acceptable. The lining is hard and tough, but can be damaged or removed by deliberate and prolonged mechanical abuse. Hot water in the pipes is limited to 160 °F but, because domestic hot water is usually regulated at 140 °F to minimize the danger of scalding, this has not presented a problem. If the pipe is cut, loose paint at the site must be removed before the system is closed.

Plans have been made to demonstrate this technology by lining the drinking water systems in four Navy buildings on the Washington Navy Yard or the Anacostia Naval Annex in Washington, DC during the summer of 1966. Specifications and quality control parameters are available for the NRL 4C lining, and installation and inspection standards are available for the installation process. One outcome of the demonstration project will be the production and distribution of technical and procurement guidance for use by any Defense activity which desires to clean and line its drinking water distribution systems. Using these documents, all future installations of pipe linings in Defense facilities may carried out according to proven standard procedures.

TABLE 1. SITES SELECTED FOR THE DEMONSTRATION PROJECT

1. ANA2-87	An old house with an addition, now used as a detention facility. The building contains a bath area with toilets, showers, and sinks at one end of the building, and two cells with toilets and sinks at the far end.
2. ANA93	A 2-story Bachelor Officers' Quarters with 30 sleeping rooms. This is similar to a commercial motel; each room has a shower, toilet and sink.
3. ANA171	The "Legends" snack bar, formerly the "Acey-Deucey" NCO club. The building has a kitchen area with sinks and two sets of men's and women's restrooms at opposite ends of the building.
4. WNY220	A four-story mixed use industrial/warehouse/office, originally constructed for use as a warehouse. Men's and women's toilets on each floor are stacked and connected by vertical supply lines.

At the conclusion of this work, the technology will be transferred to the Naval Facilities Engineering Command (NAVFAC), the Air force Office of Installations and Logistics, the Army Corps of Engineers, and their field activities. We will prepare a Guide Specification for Drinking Water Pipe Linings. NAVFAC routinely uses guide specifications for construction and repair activities of all kinds. This document will be indexed, reproduced, and distributed to engineering field activities in the same manner as current guide specifications. we will provide on-site assistance if requested for the first few installations of the coating, and will incorporate lessons learned into the guide specification. We will be available for consultation and advice after the document is issued and, if funding is available, will update the document as circumstances require.

The guide specification will contain at least the following information: applicable federal health and safety laws and regulations; indications where use of the coating, or replacement of pipe is recommended; formulation and quality control limits for the lining; safety precautions to be followed during installation; procedures for pipe cleaning, surface preparation, lining application and curing; and procedures for testing and inspecting installed linings.

CONCLUSIONS

Epoxy coatings have been formulated and all necessary certifications for contact with drinking water have been obtained. The lining will be installed in three DoD buildings this summer. Technical and procurement guidance will be made available to all DoD activities who wish to use this technology to rehabilitate drinking water systems. The technology is also applicable to waste water, fuel, and other piping systems.

ACKNOWLEDGEMENT

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REFERENCES

1. "Epoxy Linings for Shipboard Piping Systems." R. F. Brady, Jr. and J. D. Adkins, *NRL Memorandum Report 6120--94-7629*, September 30, 1994.

2. *Federal Register* 57 (154), 35630-35696, August 10, 1992.

3. At the present time two applicators offer this coating method commercially: American Pipelining Corporation, 5780 Chesapeake Court, Suite #1, San Diego, CA 92123, POC Mr. Steve Mori, tel 619-278-7991, fax 619-278-7993; and Insitu Pipe Coating Inc., 3205 Production Avenue, Oceanside, CA 92054, POC Mr. Wayne Nishimoto, tel 691-721-2577, fax 619-721-2578.

4. NSF Standard 61, "Drinking Water System Components - Health Effects." National Sanitation Foundation, Ann Arbor, Michigan.